PATENT
MAG00580P00352US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

OIPE IAP78 FEB 2 6 2007 PATENT & TRADEMARK OFFICE

In re Application Of:		)	Loop Powered Process Control Instrument Power Supply
Michael D. Flasza		)	
Serial No.:	10/670,036	)	Group Art Unit: 2816
Filed:	September 23, 2003	)	Examiner: Terry Lee Englund

LETTER OF TRANSMITTAL

Mail Stop Appeal Briefs - Patent
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Sir:

The Appellants' Brief on Appeal is filed herewith together with a fee of $250.00. Our check in the amount of $250.00 is enclosed herewith for filing the Brief on Appeal.

If any extension is required, then this should be considered a petition under 37 CFR 1.136 for such an extension. A duplicate copy of this sheet is enclosed. Please charge any petition fee or additional fee or credit any overpayment to Deposit Account No. 23-0785.

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37 CFR 1.8
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Signature: Corinne Byk
Corinne Byk

Respectfully submitted,

Date: February 22, 2007

By: [signature]
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re Application Of:	)	Loop Powered Process Control
	)	Instrument Power Supply
Michael D. Flasza	)	
	)	Examiner: Terry Lee Englund
Serial No.: 10/670,036	)	
	)	
Filed: September 23, 2003	)	Art Unit: 2816

APPELLANT'S APPEAL BRIEF

Mail Stop Appeal Briefs - Patent
Commissioner for Patents
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Alexandria, Virginia 22313-1450

Sir:

This brief is filed within two months from the date of filing the Notice of Appeal.

REAL PARTY IN INTEREST

The real party in interest is Magnetrol International, the assignee of the application.

02/26/2007 TBESHAH1 00000059 10670036

37 CFR 1.8
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Signature: Corinne Byk
Corinne Byk

RELATED APPEALS AND INTERFERENCES

There are no related appeals or interferences.

STATUS OF CLAIMS

Claims 1-20 are pending in the application, are rejected, and are at issue.

STATUS OF AMENDMENTS

No amendment was filed subsequent to final action.

SUMMARY OF CLAIMED SUBJECT MATTER

Reference to the drawings is to Figs. 1 and 2.

Claim 1 defines a loop powered process instrument 12 including a primary element 14 which senses the value of a process variable. See page 5, lines 16-18. A control circuit 26 measures the process variable and develops a control signal on a line 36 representing the process variable. An output circuit 28 is connected to terminals 16 and 18 for connection of the instrument 12 in a two-wire process loop 10. The output circuit 28 controls current on the loop 10 in accordance with the control signal on the line 36. See page 6, lines 9-15. A power supply circuit 30 is connected to the output circuit 28 and the control circuit 26 for receiving power from the two-wire process loop and supplying power to the control circuit. The power supply circuit comprises cascaded charge pump circuits 32 and 34. See specification, page 6, lines 15-18.

Claim 8 defines a loop powered process instrument 12 including a primary element 14 which senses the value of a process variable. See page 5, lines 16-18. A control circuit 26 measures the process variable and develops a control signal on a line 36 representing the process variable. An output circuit 28 is connected to terminals 16 and 18 for connection of the instrument 12 in a two-wire process loop 10. The output circuit 28 controls current on the loop 10 in accordance with the control signal on the line 36. See page 6, lines 9-15. A power supply circuit 30 is connected to the output circuit 28 and the control circuit 26 for receiving power from the two-wire process loop and supplying power to the control circuit. See specification, page 6, lines 15-18. The power supply circuit comprises a current source 40, represented by current I1, see page 9, lines 8 and 9, providing a select current to a pluarlity of cascaded switched capacitor voltage dividers 52, see page 8, lines 8-18.

Claim 16 defines an improvement in a loop powered process instrument 12 including a primary element 14 which senses the value of a process variable. See page 5, lines 16-18. A control circuit 26 measures the process variable and develops a control signal on a line 36 representing the process variable. An output circuit 28 is connected to terminal 16 and 18 for connection of the instruments 12 in a two-wire process loop 10. The output circuit 28 controls current on the loop 10 in accordance with the control signal on the line 36. See page 6, lines 9-15. The improvement comprises a power supply circuit 30 connected to the output circuit 28 and the control circuit 26 for receiving power from the two-wire process loop and supplying power to the control circuit. The power supply circuit comprises cascaded switched capacitor voltage dividers 52. See specification, page 6, lines 15-18 and page 8, lines 8-18.

GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

1. Do the drawings show every feature of the invention specified in the claim as required under 37 CFR §1.83(a)?

2. Is the specification properly objected to as containing alleged informalities?

3. Is the disclosure enabling for claims 1-20?

ARGUMENT

The objection to the drawings and specification and likewise the rejection of the claim are all interrelated. For this reason, appellant presents an overall explanation which simultaneously argues against the objections to the specification and drawing and the rejection of the claim. In so doing, reference will be made to the drawings, specification and claims, as appropriate.

Background

To understand the invention it is helpful to understand the genesis of the invention. The following is taken from the background for the present application.

Process control systems require the accurate measurement of process variables, such as temperature, pressure, level, etc. Typically, a primary element senses the value of a process variable and a transmitter develops an output having a value that varies as a function of

the process variable. For example, a level transmitter includes a primary element for sensing level and a circuit for developing an electrical signal proportional to sensed level.

An electrical transmitter must be connected to an electrical power source to operate. One form of such a transmitter, known as a four-wire transmitter, includes two terminals for connection to a power source and two terminals for carrying a loop signal proportional to the process variable. This signal can be used as an input to a controller or for purposes of indication. Because the instrument is connected directly to a power source, power consumption is a less critical factor in design and use of the same.

The use of a four-wire transmitter, as discussed above, requires the use of four wires between the transmitter and related loop control and power components. Where transmitters are remotely located, such a requirement can be undesirable owing to the significant cost of cabling. To avoid this problem, instrument manufactures have strived to develop devices known as two-wire, or loop powered, transmitters. A two-wire transmitter includes two terminals connecting to a remote power source, with the transmitter controlling loop current drawn from the power source proportional to the process variable. A typical instrument operates off of a 24 volt DC source and varies the signal current in the loop between four and twenty milliamps (mA) DC. Because of these operating requirements the design of the transmitter in terms of power consumption is critical. For example, when a low level signal of four milliamps is transmitted, there is minimal power available to be consumed by the instrument. Therefore, circuits must be designed to operate off of such minimal available power.

While low power circuits are continuously developed, there are ever increasing demands place on performance capabilities of the process control instruments. For example, with a radar level measurement device, the instruments performance is enhanced by more powerful digital signal processing techniques driven by a microcontroller. In addition to the microcontroller, there are several other circuits, such as the radar transceiver, which require electric power. To be successful, the design must use optimum processing capability and speed. This means making maximum power from the loop available to the electronics, and making efficient use of it.

Invention

The invention relates to a loop powered process instrument which makes optimum use of minimal available power. The rejection focuses on the issue of controlling loop current. How loop current is controlled is not what the invention is about. Any number of methods can be used to create and control a 4-20mA current loop, as is stated throughout the specification, as noted below. The invention relates particularly to how a designer recognizes the challenge of using minimal available loop current to power the device that controls the current loop.

Below is a copy of Fig. 1 marked up in dashed line to illustrate the "loop".

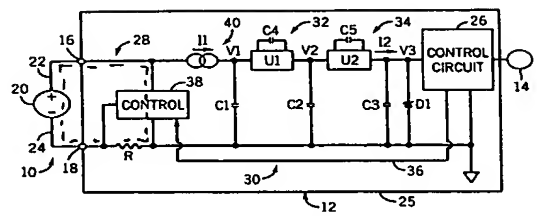

FIG. 1

As described in the specification, a process loop 10 uses a loop powered process instrument 12. The instrument 12 is connected to a remote power source 20 by two wires 22 and 24, thus the name two-wire loop. The power source 20 is typically about 24 volts DC and the instrument 12 varies signal current on the loop between 4mA and 20mA DC. See page 5, line 16 to page 6, line 3.

The instrument 12 can be used to sense numerous different process variables and is not intended to be limited to any particular type of instrument or measurement technique. See page 6, lines 4-8.

A control circuit 26 measures the process variable using the primary element 14 and develops a control signal on a line 36. An output circuit 28 controls current on the loop 10 in accordance with the control signal on the line 36. A power supply circuit 30 is connected to the output circuit 28 and the control circuit 26 for receiving power from the loop 10 and supplying power to the control circuit 26. See page 6, lines 9-18.

The output circuit 28 is <u>conventional in nature</u> **and includes a control block 38 in series with a sense resistor R and the power source 20. See page 7, lines 9 and 10. This series connection is shown in dashed line above. This series connection comprises the process loop 10** described in the specification. The control block 38 receives the process variable signal, on the line 36, and controls the 4-20mA loop current in proportion to the measured process variable, **as is well known**. See page 7, lines 12-14. The control block 38 is also connected across the sense resistor R to sense loop current **in the conventional manner**. See page 7, lines 10 and 11. Particularly, as is apparent, the loop current flows through the resistor R. The control block 38 being connected across the resistor can measure the voltage across the resistor which is equal to the current times the resistance (V=I*R). The resistor being of a known value, the control block 38 can determine current by I=V/R. This will be readily apparent to one skilled in the art.

The present invention uses charge pump circuits 32 and 34 cascaded to provide a three volt DC supply to the control circuit 26. See page 8, lines 4 and 5. Thus, the invention provides a high efficiency power supply circuit operating off of low power input using cascaded charge pump circuits, see page 11, lines 3-5.

35 U.S.C. §112 requires that the specification contain a written description of the invention to enable any person skilled in the art to make and use the same. Appellant submits that the methods and techniques for controlling loop current are conventional and well known to those skilled in the art, **as stated in the specification**, and greater detail in the specification is not required.

37 CFR §1.83 states that "conventional features disclosed in the description and claims, where their detailed illustration is not essential for a proper understanding of the invention, should be illustrated in the drawing in the form of a graphical drawing symbol or a labeled representation (e.g., a labeled rectangular box)."

The present application and drawings satisfy these requirements.

The action focuses on lack of description for how the output circuit 38 controls anything. Indeed, the invention is not directed to how loop current is controlled, but rather to a power supply circuit as part of a loop power process instrument. Appellant submits that the specification and drawings are sufficient to enable one skilled in the art to understand the teachings of an output circuit for connection to a two-wire process loop for controlling current on the loop in accordance with the control signal, as recited in, e.g., claim 1.

As evidence of the general knowledge of those skilled in the art, of record is a third party reference entitled "4-20 mA Current Loop Primer", Attachment 1. This reference illustrates that controlling loop current is conventional and well-known. Indeed, the reference on the first page under the heading "Why Use A Current Loop?" states:

> "The 4-20mA current loop shown in Figure 1 is a common method of transmitting sensor information in many industrial process-monitoring applications."

Thus, this article states that such a current loop is a common method. The second page of the reference, second paragraph, states that "[t]he transmitter amplifies and conditions

the sensor's output, then converts this voltage to a proportional 4-20mA DC current that circulates within the closed series-loop".

Also of record is a magazine article entitled "4-20mA Transmitters Alive and Kicking", October 1998, Control Engineering, Attachment 2. Control Engineering is a widely recognized publication in the instrumentation field. This article describes the use of 4-20mA current loops. Of significance is the opening statement in the article as follows:

> Because they've been around so long, everyone already knows all there is to know about 4-20 mA transmitters and how to install them.

The article otherwise goes on to discuss some basic issues in such transmitters. Again, this article supports the notion that one skilled in the art will recognize how to control a 4-20mA current loop.

Finally, of record is an Application Note AN104 of Dataforth Corporation entitled "4-20 mA Transmitters", Attachment 3. The opening line of this document, under the heading "Preamble" reads as follows:

> Over the years the 4-20 mA transmitter has become an accepted standard technique for transmitting information between field I/O and the control area.

Fig. 3 on the second page of the Dataforth reference shows the basic circuit blocks of a 4-20mA transmitter with a current source conversion circuit which establishes the current loop signal and the loop side power which generates the necessary internal voltages. In the present invention, element 28, the output circuit, corresponds functionally to the current source conversion circuit and the cascaded charge pump circuits 32 and 34 correspond to the loop side power.

Turning to the claims, claim 1, e.g., specifies a loop powered process instrument comprising a control circuit measuring a process variable and developing a control signal representing the process variable. An output circuit for connection to a two-wire process loop controls current on the loop in accordance with the control signal. A power supply circuit is connected to the output circuit and the control circuit for receiving power from the two-wire process loop and supplying power to the control circuit, comprising cascaded charge pump circuits.

At issue is whether or not the specification is enabling for an output circuit for connection to a two-wire process loop for controlling current on the loop in accordance with the control signal. Appellant submits that the disclosure is enabling.

The test for enablement is described in MPEP §2164.01. The test requires the invention be enabled so that any person skilled in the art can make and use the invention without undue experimentation. The patent need not teach, and **preferably omits**, what is well known in the art. Moreover, MPEP §2164.04 specifies that:

> A specification disclosure which contains a teaching of the manner and process of making and using an invention in terms which correspond in scope to those used in describing and defining the subject matter sought to be patented must be taken as being in compliance with the enablement requirement of 35 U.S.C. 112, first paragraph, unless there is a reason to doubt the objective truth of the statements contained therein which must be relied on for enabling support.

Further, as the Federal Circuit stated with respect to Section 112 in Atmel Corp. v. Information Storage Devices, Inc., 53 USPQ2d 1225, 1230 (Fed. Cir. 1999):

> Paragraph 1 permits resort to material outside of the specification in order to satisfy the enablement portion of the statute because it makes no sense to encumber the specification of a patent with all the knowledge of the past concerning how to make and use the claimed invention. One skilled in the art knows how to make and use a bolt, a wheel, a gear, a transistor, or a known chemical starting material. The specification would be of enormous and unnecessary length if one had to literally reinvent and describe the wheel.

In the context of the claimed invention, control of current on a two-wire process loop is like the wheel. It need not be reinvented or described. The present application describes that the invention can be used with different sensing techniques and used with conventional circuitry for controlling loop current, see page 7, lines 9-14. There is no reason to doubt the truth of these statements. Nor has the Examiner set forth why these statements should be doubted. Indeed, these statements of appellant are supported by the multiple industry publications of record herein which describe that a transmitter for a current loop is common, everybody knows all there is to know about 4-20mA transmitters, and 4-20mA transmitters have become an accepted technique for transmitting information.

As is apparent, this application need not teach to those skilled in the art that which is well known to them, i.e., controlling current on a two-wire process loop in accordance with a control signal. Indeed, the invention is not directed particularly to how the current is controlled,

but rather, in an instrument that controls loop current, a power supply supplying power to a control circuit.

Moreover, the objection to the drawings should be withdrawn, as the drawings satisfy the requirements of 37 CFR §1.83 and taken with the specification provide a sufficient disclosure for one skilled in the art to practice the invention.

For the above reasons, appellant submits that the objection to the specification and drawings should be withdrawn and likewise the rejection of the claims under §112, first paragraph, should be withdrawn.

Reversal of the rejection is requested.

Respectfully submitted,

Dated: February 22, 2007

By: ______________________
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CLAIMS APPENDIX

1. A loop powered process instrument comprising:

a control circuit measuring a process variable and developing a control signal representing the process variable;

an output circuit for connection to a two-wire process loop for controlling current on the loop in accordance with the control signal; and

a power supply circuit connected to the output circuit and the control circuit for receiving power from the two-wire process loop and supplying power to the control circuit, comprising cascaded charge pump circuits.

2. The loop powered process instrument of claim 1 wherein the charge pump circuits comprise divide-by-two charge pump circuits.

3. The loop powered process instrument of claim 1 wherein the charge pump circuits each have an efficiency of about 95%.

4. The loop powered process instrument of claim 1 wherein the power supply circuit comprises a current source connecting the cascaded charge pump circuits to the output circuit.

5. The loop powered process instrument of claim 1 wherein the power supply circuit comprises a regulator diode connecting an output of the cascaded charge pump circuits to the control circuit.

6. The loop powered process instrument of claim 1 wherein the power supply circuit has an input of about 13 volts and 3.5 mA and an output of about 3 volts and about 13 mA.

7. The loop powered process instrument of claim 1 wherein the power supply circuit has an overall efficiency of about 90%.

8. A loop powered process instrument comprising:

a control circuit measuring a process variable and developing a control signal representing the process variable;

an output circuit for connection to a two-wire process loop for controlling current on the loop in accordance with the control signal; and

a power supply circuit connected to the output circuit and the control circuit for receiving power from the two-wire process loop and supplying power to the control circuit, comprising a current source providing a select current to a plurality of cascaded switched capacitor voltage dividers.

9. The loop powered process instrument of claim 8 wherein the switched capacitor voltage dividers comprise divide-by-two charge pump circuits.

10. The loop powered process instrument of claim 8 wherein the switched capacitor voltage dividers each have an overall efficiency of at least 90%.

11. The loop powered process instrument of claim 8 wherein the switched capacitor voltage dividers each have an efficiency of about 95%.

12. The loop powered process instrument of claim 8 wherein the power supply circuit comprises a regulator diode connecting an output of the cascaded switched capacitor voltage dividers to the control circuit.

13. The loop powered process instrument of claim 8 wherein the power supply circuit has an input of about 13 volts and 3.5 mA and an output of about 3 volts and about 13 mA.

14. The loop powered process instrument of claim 8 wherein the power supply circuit has an overall efficiency of about 90%.

15. The loop powered process instrument of claim 8 wherein the switched capacitor voltage dividers comprise CMOS switched capacitor voltage converters each having a pump capacitance and an output capacitance.

16. In a loop powered process instrument including a control circuit measuring a process variable and developing a control signal representing the process variable and an output circuit for connection to a two-wire process loop for controlling current on the loop in accordance with the control signal, the improvement comprising:

a power supply circuit connected to the output circuit and the control circuit for receiving power from the two-wire process loop and supplying power to the control circuit, comprising a plurality of cascaded switched capacitor voltage dividers.

17. The loop powered process instrument of claim 16 wherein the improvement comprises two cascaded divide-by-two charge pump circuits each having an efficiency of about 95%.

18. The loop powered process instrument of claim 16 wherein the switched capacitor voltage dividers comprise CMOS switched capacitor voltage converters each having a pump capacitance and an output capacitance.

19. The loop powered process instrument of claim 16 wherein the power supply circuit has an input of about 13 volts and 3.5 mA and an output of about 3 volts and about 13 mA.

20. The loop powered process instrument of claim 16 wherein the power supply circuit comprises a current source connecting the cascaded switched capacitor voltage dividers to the output circuit and a regulator diode connecting an output of the cascaded switched capacitor voltage dividers to the control circuit.

EVIDENCE APPENDIX

Submitted herewith are the following attachments:

1. DATEL "4-20mA Current Loop Primer", filed with Amendment A on April 25, 2005, and entered with the Office action mailed August 10, 2005.

2. Control Engineering on line article "4-20mA Transmitters Alive and Kicking";

3. DATAFORTH Application Note AN104 "4-20mA Transmitters"; both filed with Amendment B on May 24, 2006, and entered in the final action mailed September 20, 2006.

RELATED PROCEEDINGS APPENDIX

There are no related proceedings.

4-20mA Current Loop Primer

Introduction

This application note's primary goal is to provide an easy-to-understand primer for users who are not familiar with 4-20mA current-loops and their applications. Some of the many topics discussed include: why, and where, 4-20mA current loops are used; the functions of the four components found in a typical application; the electrical terminology and basic theory needed to understand current loop operation. Users looking for product-specific information and/or typical wiring diagrams for DATEL's 4-20mA loop- and locally-powered process monitors are referred to DMS Application Note 21, titled "Transmitter Types and Loop Configurations."

Despite the fact that the currents (4-20mA) and voltages (+12 to +24V) present in a typical current loop application are relatively low, please keep in mind that all local and national wiring codes, along with any applicable safety regulations, must be observed. Also, this application note is intended to be used as a supplement to all pertinent equipment-manufacturers' published data sheets, including the sensor/transducer, the transmitter, the loop power supply, and the display instrumentation.

Why Use a Current Loop?

The 4-20mA current loop shown in Figure 1 is a common method of transmitting sensor information in many industrial process-monitoring applications. A sensor is a device used to measure physical parameters such as temperature, pressure, speed, liquid flow rates, etc. Transmitting sensor information via a current loop is particularly useful when the information has to be sent to a remote location over long distances (1000 feet, or more). The loop's operation is straightforward: a sensor's output voltage is first converted to a proportional current, with 4mA normally representing the sensor's zero-level output, and 20mA representing the sensor's full-scale output. Then, a receiver at the remote end converts the 4-20mA current back into a voltage which in turn can be further processed by a computer or display module.

However, transmitting a sensor's output as a voltage over long distances has several drawbacks. Unless very high input-impedance devices are used, transmitting voltages over long distances produces correspondingly lower voltages at the receiving end due to wiring and interconnect resistances. However, high-impedance instruments can be sensitive to noise pickup since the lengthy signal-carrying wires often run in close proximity to other electrically-noisy system wiring. Shielded wires can be used to minimize noise pickup, but their high cost may be prohibitive when long distances are involved.

Sending a current over long distances produces voltage losses proportional to the wiring's length. However, these voltage losses—also known as "loop drops"—do not reduce the 4-20mA current as long as the transmitter and loop supply can compensate for these drops. The magnitude of the current in the loop is not affected by voltage drops in the system wiring since all of the current (i.e., electrons) originating at the negative (-) terminal of the loop power supply has to return back to its positive (+) terminal—fortunately, electrons cannot easily jump out of wires!

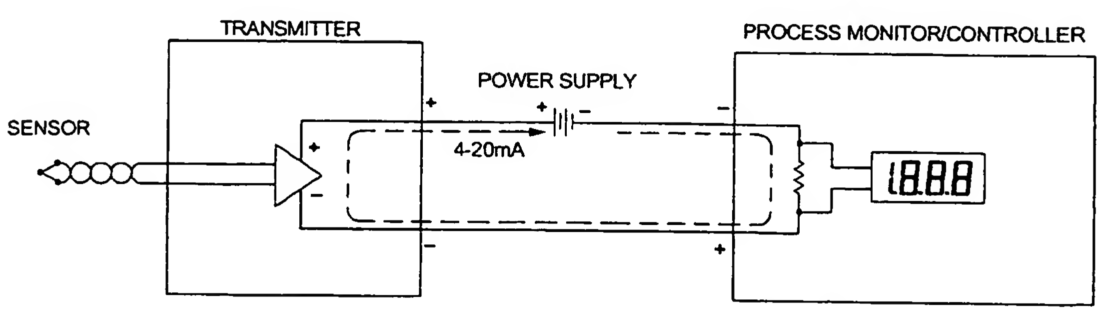


Figure 1. Typical Components Used in a Loop Powered Application

Attachment 1

Current Loop Components

A typical 4-20mA current-loop circuit is made up of four individual elements: a sensor/transducer; a voltage-to-current converter (commonly referred to as a transmitter and/or signal conditioner); a loop power supply; and a receiver/monitor. In loop powered applications, all four elements are connected in a closed, series-circuit, loop configuration (see Figure 1).

Sensors provide an output voltage whose value represents the physical parameter being measured. (For example, a thermocouple is a type of sensor which provides a very low-level output voltage that is proportional to its ambient temperature.) The transmitter amplifies and conditions the sensor's output, and then converts this voltage to a proportional 4-20mA dc-current that circulates within the closed series-loop. The receiver/monitor, normally a subsection of a panel meter or data acquisition system, converts the 4-20mA current back into a voltage which can be further processed and/or displayed.

The loop power-supply generally provides all operating power to the transmitter and receiver, and any other loop components that require a well-regulated dc voltage. In loop-powered applications, the power supply's internal elements also furnish a path for closing the series loop. +24V is still the most widely used power supply voltage in 4-20mA process monitoring applications. This is due to the fact that +24V is also used to power many other instruments and electromechanical components commonly found in industrial environments. Lower supply voltages, such as +12V, are also popular since they are used in computer-based systems.

Loop Drops

One of a process monitor's most important specifications—be it a loop-powered or locally powered device—is the total resistance (or "burden") it presents to the transmitter's output driver. Most transmitter's data sheets specify the maximum loop resistance the transmitter can drive while still providing a full-scale 20mA output (the worst-case level with regards to loop burden).

Ohm's Law states that the voltage drop developed across a current-carrying resistor can be found by multiplying the resistor's value by the current passing through it. Stated in mathematical terms:

$$E = I \times R$$

where E is the voltage drop in volts, I is the current through the resistor in amperes, and R is the resistor's value in Ohms (the 'Ω' symbol is commonly used to represent Ohms).

The sum of the voltage drops around a series loop has to be equal to the supply voltage. For example, when a loop-powered application is powered from a 24V power source, the sum of all the voltage drops around the series loop has to also equal 24V. Every component through which the 4-20mA loop current passes develops a maximum voltage drop equal to that component's resistance multiplied by 0.020 Amperes (20mA). For example, referring to Figure 2 the DMS-20PC-4/20S's 250Ω resistance yields a maximum loop drop of :

$$250\Omega \times 0.020A = 5.0V$$

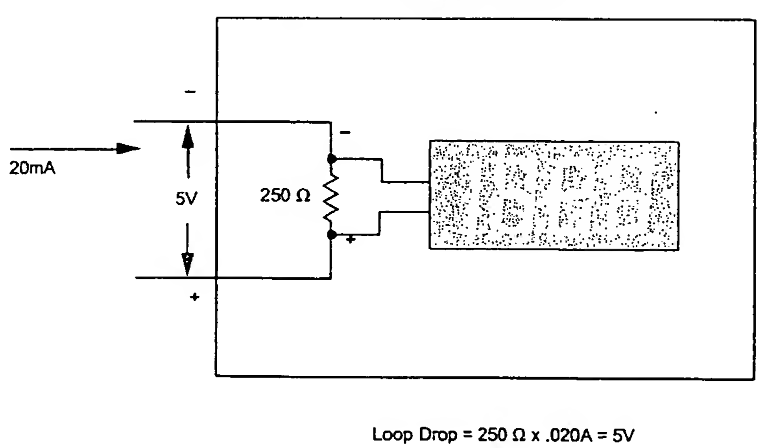


Figure 2. Calculating Loop Drops

Transmitter Ratings

With the above loop-drop theory in mind, and assuming a +24V loop-powered application in which the transmitter's minimum operating voltage is 8V, and the process monitor drops only 4V, a logical question which arises is what happens to the "extra" 12V? The extra 12V has to be dropped entirely by the transmitter since most process monitors have purely resistive inputs combined with zener diodes that limit their maximum voltage drop.

Transmitters usually state both minimum and maximum operating voltages. The minimum voltage is that which is required to ensure proper transmitter operation, while the maximum voltage is determined by its maximum rated power-dissipation, as well as by its semiconductors' breakdown ratings. A transmitter's power dissipation can be determined by multiplying its loop drop by the highest anticipated output current, usually, but not always, 20mA. For example, if a transmitter drops 30V at an overrange output level of 30mA, its power dissipation is:

30V x 0.030A = 0.9 watts

Wiring Resistance

Because copper wires exhibit a dc-resistance directly proportional to their length and gauge (diameter), this application note would not be complete without discussing the important topic of wiring—specifically the effects wiring resistance has on overall system performance.

Applications in which two or more loop-monitoring devices are connected over very long, 2-way wiring distances (1000-2000 feet) normally use +24V supplies because many transmitters require a minimum 8V-supply for proper operation. When this 8-volt minimum is added to the typical 3-4 volts dropped by each process monitor and the 2-4 volts dropped in the system wiring and interconnects, the required minimum supply voltage can easily exceed 16V. The following worked-out example will illustrate these important concepts.

The voltage drop developed along a given length of wire is found by multiplying the wire's total resistance by the current passing through it. The wire's total resistance is found by looking up its resistance (usually expressed in Ohms per 1000 feet) in a wire specifications table. Referring to Figure 3 if a transmitter's output is delivered to a remote process monitor using 2000 feet (660 meters) of 26-guage, solid copper wire having a resistance of 40.8Ω per 1000 feet, the one-way voltage dropped by the wire when the transmitter's output is 20mA is equal to:

E = 0.020 Amperes x [2000 feet x (40.8Ω /1000 feet)]

E = 0.020A x 81.6Ω = 1.63V

However, the current must travel 2000 feet down to the process monitor and another 2000 feet back to the transmitter's "+" output terminal, for a total of 4000 feet. As noted above, 26-gauge wire has a resistance of 40.8Ω per 1000 feet, yielding a total loop resistance (R) equal to 4000 feet x (40.8Ω /1000 feet) = 163.2Ω. The total voltage dropped over the 4000 feet of wiring is therefore:

E = 0.020A x 163.2Ω

E = 3.27V.

Looking down the loop towards the remote process monitor, the transmitter sees the sum of the 3.27V wire drop and the 5.0V process-monitor drop, for a total loop-drop of 8.27V. If the transmitter itself requires a minimum of 8V (this is also considered a voltage drop) for proper operation, the lowest power supply voltage required for the system shown in Figure 3 is 16.3V.

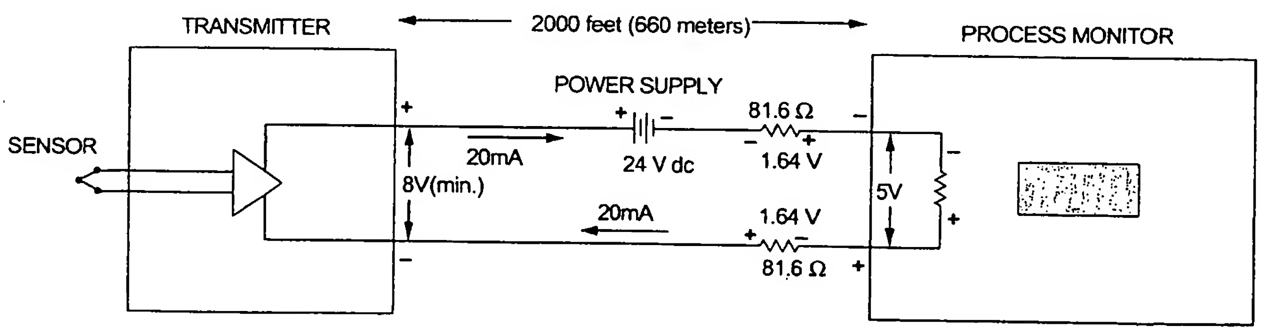


Figure 3. Wiring Resistance Effects

October, 1998 Control Engineering

4-20 mA Transmitters Alive and Kicking

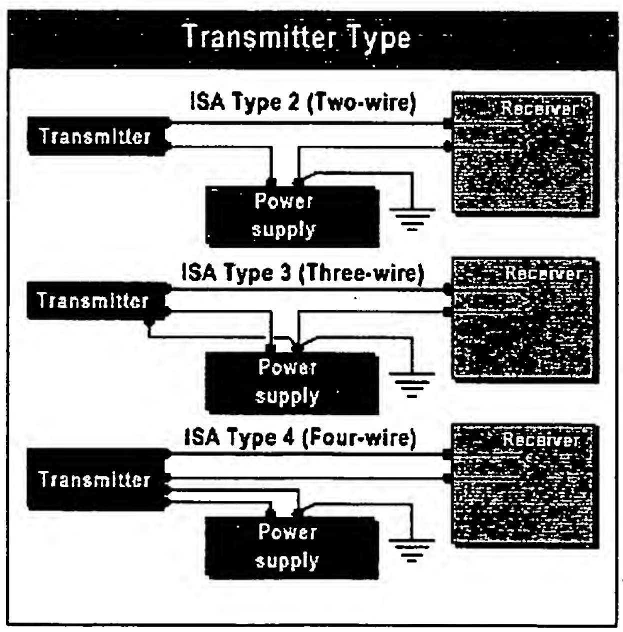
Fieldbus is everyone's hot topic, but 4-20 mA measurements are still the mainstay.

Dave Harrold, CONTROL ENGINEERING

Sidebar
List of 4-20 mA Terms

Because they've been around so long, everyone already knows all there is to know about 4-20 mA transmitters and how to install them. But, if so much is known about selecting and installing 4-20 mA transmitters, why do the same questions keep coming up? Questions like:

- "What is the difference between two-, three- and four-wire transmitters?"
- "Are there issues when mixing two- and four-wire transmitters in the same control system?"
- "When and why would line isolators be necessary?"
- "When and why would intrinsic safety barriers be used?"
- "What happens if there are isolators, intrinsic barriers, and HART transmitters all in the same installation?"
- And my personal favorite, "Why doesn't the process variable ever reach 100%?"



ISA S50.01 categorizes transmitters into two-wire, three-wire, or four-wire types.

Transmitter classifications

Understanding differences between two-, three- and four-wire devices will help clear up several of

Attachment 2

the questions

ANSI/ISA-S50.1-1982 (R-1992) standard *Compatibility of Analog Signals for Electronic Industrial Process Instruments* established transmitter type classifications as being the number of wires (2, 3, or 4) required to provide power and output circuits (see Transmitter Type). (Shield and input circuit wiring are excluded.)

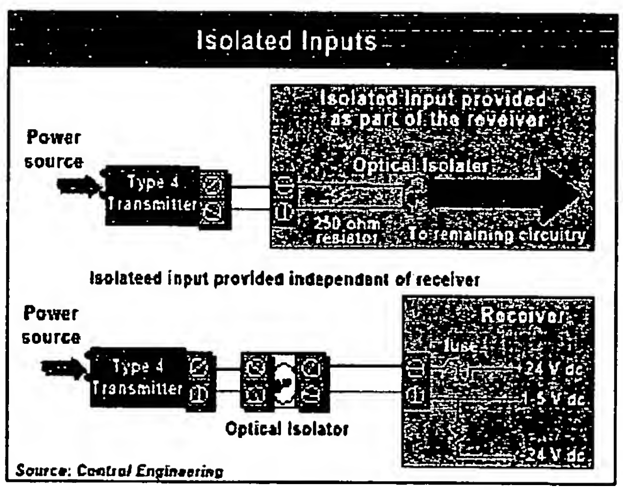
Four-wire (Type 4) transmitters use two wires to power the transmitter and two wires to provide the 4-20 mA output signal and are usually not used for conventional pressure, temperature, or level measurements.

For example, magnetic flowmeters often include a sensing element and separate enclosure containing a power supply and other electronic components requiring a separate power source. The electronics enclosure is mounted near the sensor because of distance restrictions, . This results in a four-wire installation where two wires provide electrical power, and two wires transmit the output signal to a receiving device, such as a distributed control system, a programmable control system, a data acquisition system, a recorder, or an indicator.

Plant topologies frequently place transmitters at significant distances from the receiver to which they are connected. When four-wire transmitters are used, the power source for the transmitter can be different than the power source for the receiving device. Unless careful maintenance is taken to isolate between electrical systems, ground loops are formed, introducing unsafe conditions at worst and electrical "noise" at a minimum. (Like the "hum" you hear coming from your stereo speakers only when the sump pump kicks on.)

Electrical ground loops can occur in two ways: When components in the same system receive power from different sources with different grounds, or when the ground potential between two connected pieces of equipment is not identical. A potential difference in the grounds causes a current flow in the interconnec-ting wiring. The receiver treats all incoming current flow the same producing an incorrectreading.

Preventing ground loops in four-wire transmitter circuits can be as simple as specifying isolated input channels for the receiving device (see Isolated Inputs). Receiver isolated inputs may be physically different input cards and terminations, or use of specific terminal combinations. When isolated input channels are not available for the receiver, separate line isolators should be used.



Transmitter and receiver isolation is necessary when different power sources are involved to prevent the dreaded ground loop.

Regardless of how achieved, it's good practice to provide electrical isolation between four-wire transmitters and their receiver. ISA's S50.01 standard states, "In no event should transmitters with grounded outputs be connected to grounded receivers. They require an isolator in the loop or floating receiver system."

Two-wire (Type 2) transmitters contain circuitry to vary the amount of current flow but require an external source of excitation power.

Three-wire (Type 3) transmitters require the same design and installation considerations as two-wire transmitters.

Intrinsic safety

Intrinsic safety (IS) involves designing elec-tronic circuits in such a way that the circuitcannot release sufficient energy to ignite hazardous materials in the surrounding atmosphere under any combination of component failure, design flaw, or operating and maintenance faults.

Intrinsically safe installations can be achieved through inherent system design, by selecting individually approved devices (also called entity method), or by using barriers.

Inherently designed installations require every device in the system to be individually designed to constrain field energy levels, regardless of faults or other operating conditions. When properly implemented, this approach provides an extremely high degree of protection. However, open control systems introduce system approval challenges beyond what most process control engineers are willing to accept.

Entity approval methods allow barriers and field devices to be tested and approved individually. Using the safety parameters assigned to each device, users can select a mixture of IS approved equipment from different manufacturers without need for additional IS approvals.

Use of barriers to achieve intrinsic safety is the most common solution and involves placement of safety barriers in signal wiring between safe and hazardous areas. Barriers are available using either active (galvanically isolated) or passive designs (see Intrinsic Safety Barriers). Active barriers combine transformers and optoisolators, or relays to form an isolation safety barrier. Passive barriers use resistors and diodes to form the safety barrier.

Intrinsic barriers are designed to limit the amount of current and voltage passing into the hazardous area below the ignition point of the flammable or explosive atmosphere. Depending on several criteria, including barrier design, power source, and area classification, it may be necessary to install a safety barrier in both wires. However, most dc circuits can be safely grounded at one point without affecting the power supply's operation. If one of the wires can be attached to a designated IS ground, the need to install a barrier on that wire is eliminated. Designating an IS ground requires special considerations, including prevention of introducing ground loops into the circuit.

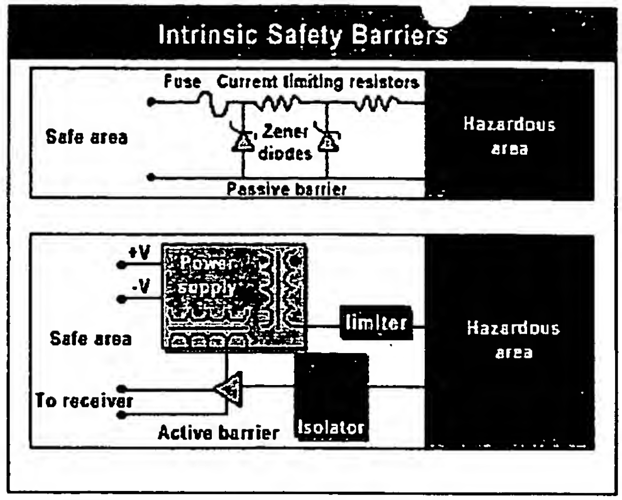
Using approved intrinsically safe techniques to protect hazardous atmospheres remains optional in many industries and world areas; explosion proofing is the alternative.

Benefits of intrinsically safe installations include:

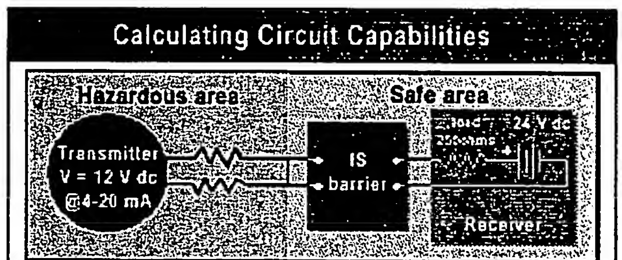
- All devices are accessible--no testing for gas, or explosion-proof housings to open;
- Personnel safety is assured because of low-voltage operation; and
- Standard wiring techniques in open cable trays or light conduit save on initial installation material and labor costs.

HART and 4-20 mA

HART's (Highway Addressable Remote Transducer) protocol makes use of the Bell 202 frequency shift keying (FSK) standard to superimpose low-level digital signals on the 4-20 mA circuit enabling more information than just the process variable to communicate between transmitters and receivers.



Intrinsic safety barriers use passive or active components to limit voltageand current into hazardous areas. Passive barriers frequently use redundant components for added protection.



Resistance available in loop	R loop = 24 Volts/20mA = 1200 ohms
Resistance used before barrier	R trans. = 12 Volts/20mA = 600 ohms R load = 250 ohms R leads = 10 ohms
Resistance available for barrier	R max for barrier = 1200 - (600+250 + 10) = 340ohms

If the barrier resistance is greater than 340 ohms, a full scale signal will never reach 20mA, it will be a lower value. For instance, if the barrier resistance is 500 ohms, the maximum mA output will be 24 V/(500ohms + 5ohms + 600ohms) = 17.6mA. For this loop to function properly, the maximum end-to-end resistance of the barrier(through both signal paths) must be less than or equal to 340ohms.

Determining if a 4-20 mA circuit has sufficient voltage to reach 100% readings is a simple, but important exercise to ensure circuit integrity.

HART's protocol *command set* is organized into three groups. Universal commands are implemented by all HART devices and provide interoperability across products from different manufacturers. Universal commands include: man- ufacturer and device type; primary variable and units; current output and percent of range; four predefined dynamic variables; eight-character tag, 16 character descriptor, and date; and several more.

HART's *common-practice command set* is used in many HART field devices, but not all, and include such functions as: writable transmitter ranges; ability to set zero and span; perform self-test; and more. *Device-specific commands* are the third set and are unique to a particular field device. Functions of the device-specific command set include: start, stop, or clear totalizer; select primary variable; PID setpoint, and tuning parameter manipulation.

Using HART transmitters in intrinsically safe installations requires special isolated (active) intrinsic barriers capable of passing the digital FSK data while maintaining safety on the 4-20 mA circuit.

Driving the circuit

No steering wheel is provided, but the need for power is critical in achieving robust 4-20 mA installations. A symptom of an under-powered 4-20 mA circuit is the inability of the transmitter to produce a 100% output reading. Depending on how the variable is used, inability for the receiver to obtain 100% transmitter values can create anything from a mere nuisance to an unsafe

condition.

Understanding the electrical response of different transmitters is key in designing, installing, and maintaining 4-20 mA loops with sufficient power to operate through the entire variable range.

Establishing transmitter interoperability was a major goal of ISA's S50.01 standards committee. Besides the transmitter type classifications discussed earlier, S50.01 established class suffixes (H, L, and U) to identify a transmitters load resistance capability with respect to its power supply voltages (see table). Combining type and class classifications, a Type-2L transmitter from one manufacturer can replace one from another manufacturer withoutchanging other devices in the circuit.

Transmitter Class Suffix Classifications

	H	L	U
Load Resistance (ohms)	300	800	300 to 800
Minimum supply voltage	23 V dc	32.7 V d	23 to 32.7 V dc
Source: ANSI/ISA-S50.01-1982 (R-1992)			

To avoid installing an underpowered 4-20 mA circuit, and later the question "Why does my process variable never reach 100%?," the voltage drop contribution of each device must be considered (see Figure 4). Likewise, any new devices added to the circuit, such as replacing a blind transmitter with one that includes a local readout, deserve reviews to ensure circuit integrity.

Analog (4-20 mA) transmitters have been around a long time, and most are operating just fine. Fieldbus technologies promise unprecedented information about what ishappening within processes, but it's likely to take at least two decades before digital fieldbus completely replaces 4-20 mA. In the meantime, transmitters providing critical measure-ments deserve periodic reviews of power, grounding, isolation, and protection elements that may reveal sources of unwanted measurement gremlins. h

For more information, visit ISA web site at www.isa.org/standards/index.html.

For more information on ANSI standards visit www.ansi.org/public/std-info.html.

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List of 4-20 mA Terms

Type 2 transmitters require two wires to simultaneously carry excitation power and the output signal.

Type 3 transmitters require three wires to simultaneously carry excitation power and the output signal.

Type 4 transmitters require four wires. Two wires for excitation power, and two wires for the output signal.

Two-wire transmitters -See Type 2.

Three-wire transmitters - See Type 3.

Four-wire transmitters - See Type 4.

Single-ended transmitters - See Type 2 or Type 3.

Self-powered transmitters - See Type 4.

Nonisolated transmitters are type 2 or type 3 used in an ungrounded circuit.

Power isolate .ansmitters are type 4 used in an ungroun , circuit.

Input-isolated transmitters are type 2 or type 3 used in a grounded circuit.

Fully isolated transmitters are type 4 used in a grounded circuit.

Dropping resistors are precision resistors, typically 250 ohms ±0.25 ohms with a temperature coefficient of not more than 0.01%/8C, used to convert 4-20 mA signals to 1-5 V dc signals.

Range resistors - See dropping resistors.

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Comments? Send an e-mail to dharrold@cahners.com.

Control Engineering - October 1998

APPLICATION NOTE

DID YOU KNOW ?
In 1827 Georg Simon Ohm, a German physicist, published his work, *The Galvanic Chain, Mathematically Treated*, which was the basis of "Ohm's Law". Ohm's work was initially denounced by critics of the time as a "web of naked fancies"; nonetheless, during his lifetime, he did receive the credit and fame his efforts deserved. In his honor, the unit of electrical resistance bears his name, Ohm.

4-20 mA Transmitters

Preamble

Over the years the 4-20 mA transmitter has become an accepted standard technique for transmitting information between field I/O and the control area. New network type transmission schemes are trying to become "the" standard. Meanwhile there are thousands of I/O points and associated control components that will continue to use the analog current loop method for transmitting data.

Figure 1 illustrates four basic steps inherent in a process control system. First, data is extracted from the process, followed next by analytical examination and interpretation. Once data is properly interpreted, the next step is a decision on the appropriate action. Lastly, the necessary action must be implemented. The distribution of these steps depend on process layout and the control philosophy adopted.

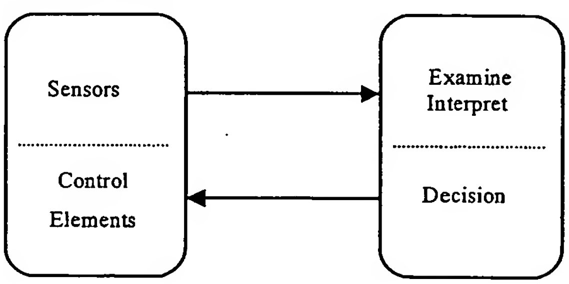

Figure 1
Basic Process Control System

Most all process control systems are distributed throughout a plant site and information flow may be over long distances. Transmitting data over considerable distances often causes major problems in distributed process control systems.

Transmitting data reliably has prompted many different communication schemes and associated products, some of which employ smart electronics in the I/O sensors and control elements.

Long before the "electronic age", process control was dominated by pneumatics. Ratio controllers, PID controllers, actuators, and recorders were all pneumatic. The standard was a 3 to 15 psi pneumatic signal, where 3 psi was the "live" zero. As computer process control began to evolve in the early 1950's, the signal transmission technique shifted from 3-15 psi to 4-20 mA signals., where 4 mA was the "live" zero. A "real" dead zero has always been an alarm condition.

The 4-20 mA Transmitter

A simplified current loop is schematically shown in Figure 2. An ideal Norton current source composed of Isignal, and Rsignal models the 4-20 mA transmitter. The line resistance is shown as Rline, and Vnoise represents random induced loop noise. In this example, a 500-ohm controller and a 250-ohm digital display are connected in series with the signal current. The loop is powered by a 24 volt dc supply.

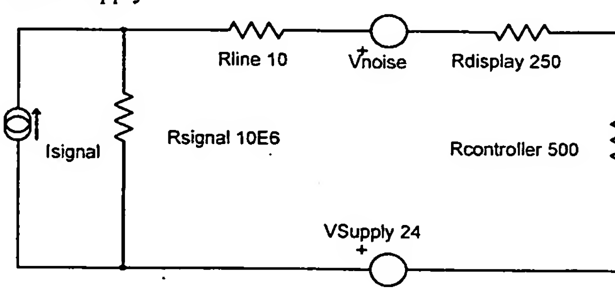

Figure 2
Current Loop Schematic

Several advantages of this type current loop are as follows;

- Signal voltage at any load is (Isignal * Rload), which is independent of supply voltage variations and line resistance (Rline).
- Random induced loop noise voltage at any load is;

  Vnoise * (Rload)/(Sum all Rloads + Rline +Rsignal)

Attachment 3

Note that loop noise at a load is reduced by the factor; (Rload)/(Sum all Rloads + Rline +Rsignal). In this example, a 10 volt induced loop noise voltage appears at the controller input as a 0.5 mV error. The controller is a 10 volt FS device (20mA * 500Ω =10) and 0.5 mV represents an error of 0.005 %.

- Supply voltage variations are reduced at any load by the same factor as shown above.

- Multiple loads can be series connected in a transmitter loop, providing considerable control and display opportunities. Loads today typically have full scale input requirements of 1 volt, 5 volts, and 10 volts. Typical 4-20mA transmitters require a voltage across their output terminals to maintain the device within its operational specifications. This voltage is often referred to as "compliance voltage" and has a rather wide range. For example, in Figure 2 the loop voltage (compliance) available for the transmitter is; (Vsupply – all load FS voltages - line IR drops); specifically, (24 volts – 15 volts - 2 mV). Depending on transmitter specifications, a larger supply voltage may be required or perhaps a 5 volt (250 Ω) controller.

  It is noteworthy to observe that selecting a supply needs to be consistent with the number and type of series loads and the required 4-20 mA transmitter "compliance" voltage.

Multiple series loads, wide variation in supply voltage, and some inherent noise immunity are advantages of current loop transmitters.

Figure 3 shows the basic internal circuit blocks of a 4-20 mA transmitter. These circuits provide the following functionality;

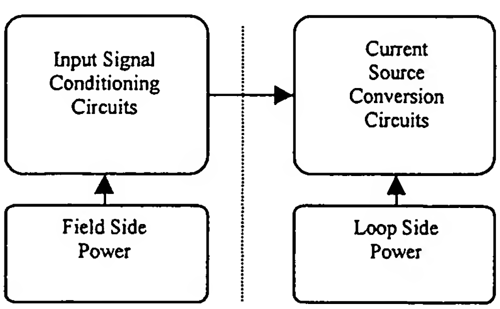

Figure 3
Basic 4-20 mA Circuit Functions

- Input Signal conditioning circuits provide appropriate interfacing for all types of inputs, such as; thermocouples, RTDs, AC-DC voltages and currents, strain gauges. Many 4-20 mA modules have "smart" signal conditioning functionality that provide linearization, and mathematical manipulations.

- Power circuits generate all the necessary internal voltages required and are energized from either a local power source or the actual current loop.

- Current conversion circuits establish the 4-20 mA current loop signal.

- The dashed line in Figure 3 illustrates isolation between the field side and the output loop side. Isolation is an extremely important aspect of signal transmission. Signal loops, power supplies, and grounds should always be completely isolated from each other.

Standards and Definitions for 4-20 mA Transmitters

The American National Standards Institute (ANSI) and The Instrumentation Systems, and Automation Society, (ISA) have numerous documents on signal transmission including 4-20 mA transmitters. See References at the end of this article for more details.

The following was taken from; ANSI/ISA-S50.1-1982 (R1992) *Compatibility of Analog Signals for Electronic Industrial Process Instruments.*

Type numbers with suffix letters are used as transmitter identifiers. Type number is the number of wires necessary to provide transmitter power. Shields and IO wires are excluded. Suffix letters identify the load resistance capability.

Figure 4 illustrates three basic transmitter types.

- Type 2 is a 2-wire transmitter energized by the loop current where the loop source voltage (compliance) is included in the receiver. The transmitter floats and signal ground is in the receiver.

- Type 3 is a 3-wire transmitter energized by a supply voltage at the transmitter. The transmitter sources the loop current. Transmitter common is connected to receiver common

- Type 4 is a 4-wire transmitter energized by a supply voltage at the transmitter. The transmitter sources the loop current to a floating receiver load.

If a transmitter has field inputs, which provide signals referenced to field grounds potential ground loops exist. This potentially will cause signal gradation.

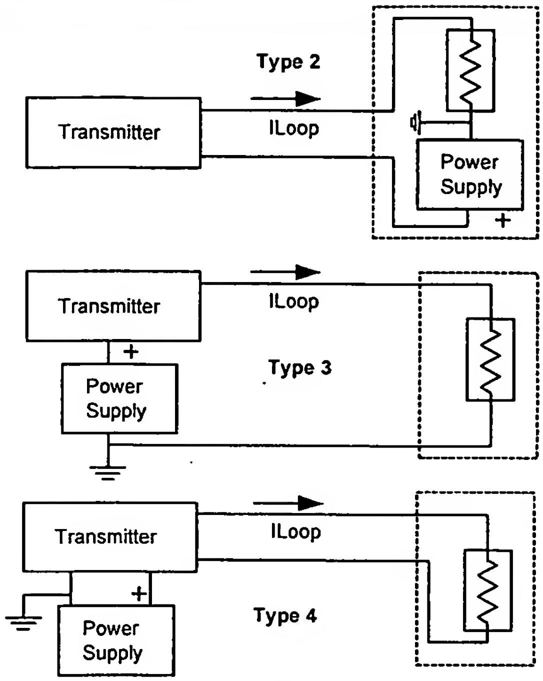

Figure 4
Transmitter Types

Table 1 shows transmitter class designations. It is necessary to understand that all 4-20 mA transmitters may not necessarily be identical in their ability to provide current into different loads. For example, a typical 4-20mA transmitter module could not drive a 100k-ohm load. This would require a compliance source of 2000 volts (20mAx100kΩ). The class standard ensures that modules of identical classes are interchangeable with respect to their drive capabilities. It is noteworthy to mention here that one should always completely examine all module specifications before replacing units..

Table 1
Class Designations

	Class L	Class H	Class U
Load Resistance Minimum	300	800	300 to 800
Supply Voltage Minimum	23	32.7	23 to 32.7

Practical 4-20 mA Circuit

Field inputs are usually referenced to field grounds or in some cases actually connected to a field ground (for example, the grounded thermocouple). Receiver grounds are rarely identical to field grounds; therefore, isolation is required to eliminate potential ground loop problems. Figure 5 illustrates Dataforth's basic block diagram concept of isolated 2-wire current loop transmitters.

Dataforth's transmitters provide;

- Transformer isolation of signals and power
- 2-wire loop powered current transmission (receiver supplies only compliance voltage)
- Field surge suppression, protection, and excitation
- Input and Output Low Pass Filtering
- Output surge suppression, protection
- Data linearization and manipulation

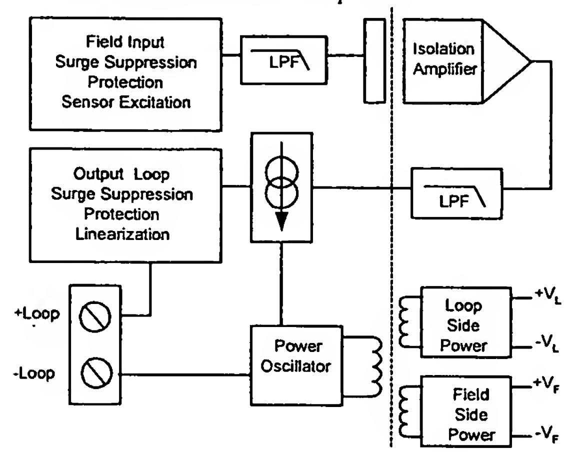

Figure 5
Dataforth Basic Isolated Current Transmitter

The reader is encouraged to visit Dataforth's website www.Dataforth.com for complete detail information on all Dataforth's product and additional application information.

For specific Dataforth 4-20mA-loop products, visit the following links:
http://www.dataforth.com/catalog/doc_generator.asp?doc_id=390
http://www.dataforth.com/catalog/doc_generator.asp?doc_id=364
http://www.dataforth.com/catalog/doc_generator.asp?doc_id=472

Listed below are some additional references.

References:

1. ANSI/ISA-50.1-1982 (R1992) formerly ANSI/ISA-S50.1-1982 (R1992) *Compatibility of Analog Signals for Electronic Industrial Process Instruments*
2. http://www.ISA.org/
3. http://www.ANSI.org/
4. http://www.nssn.org/
5. *Control Engineering* http://www.controleng.com/archives/1998/ctl1001.98/10a929.htm#List